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Organochlorine Contaminants in Ambient Waters of Lake Ontario

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Abstract

During October 1983, 36-L water samples were collected at 14 stations in Lake Ontario and analyzed for a range (23) of organochlorine contaminants: chlorobenzenes, pesticides and their by-products, and polychlorinated biphenyls (PCBs). Fifteen of the 23 compounds analyzed were ubiquitous in distribution and, of the remaining eight compounds, toxaphene, mirex, photomirex and dichlorobenzenes were undetected. A station located east of Hamilton Harbour was ranked highest in total PCBs (3.1 $ng \cdot L^{-1}$), oxychlordane (0.263 $ng \cdot L^{-1}$) and heptachlor epoxide (0.375 $ng \cdot L^{-1}$), and ranged second highest in total DDT (tDDT). The highest concentrations for α-BHC (8.08 $ng \cdot L^{-1}$), α-chlordane and γ-chlordane (0.046 and 0.062 $ng \cdot L^{-1}$, respectively) were recorded at a station situated just west of Toronto Harbour. Most of the chlorobenzenes were highest offshore of Eighteen Mile Creek; sampling, however, was insufficient to demonstrate that the observed levels were the result of the Niagara River plume. While pesticide levels did not exceed current criteria established by the Great Lakes Water Quality Agreement and the United States Environmental Protection Agency, concentrations of lindane, dieldrin, endrin, and tDDT were within one order of magnitude of these criteria.

Résumé

En octobre 1983, des échantillons de 36 L d'eau ont été prélevés à 14 stations du lac Ontario et analysés pour déceler la présence de 23 contaminants organochlorés comprenant des chlorobenzènes, des pesticides ainsi que leurs sous-produits et des biphényles polychlorés (BPC). Des 23 composés dosés, quinze étaient présents dans tous les échantillons, et, des huit autres composés, le toxaphène, le mirex, le photomirex et les dichlorobenzènes n'ont pas été décelés. L'analyse de l'eau prélevée à une station située à l'est du port de Hamilton a révélé que les concentrations de BPC totaux (3.1 $ng \cdot L^{-1}$), d'oxychlordane (0.263 $ng \cdot L^{-1}$) et d'heptachlore-époxyde (0.375 $ng \cdot L^{-1}$) étaient le plus élevées à cet endroit, qui s'est classé au deuxième rang pour la concentration de DDT total. Les plus fortes concentrations d'α-BHC (8.08 $ng \cdot L^{-1}$), d'α-chlordane (0.046 $ng \cdot L^{-1}$) et de γ-chlordane (0.062 $ng \cdot L^{-1}$) ont été enregistrées à une station située juste à l'ouest du port de Toronto. C'est au large de l'embouchure du ruisseau Eighteen Mile que la concentration de la plupart des chlorobenzènes était le plus élevée; toutefois, il a été impossible de prouver, en raison du nombre insuffisant d'échantillons, que la présence de ces composés en forte quantité était due au panache de la rivière Niagara. Même si les concentrations de pesticides n'ont pas été supérieures aux normes établies en vertu de l'Accord relatif à la qualité de l'eau dans les Grands lacs et par l'Environmental Protection Agency des États-Unis, les concentrations de lindane, de dieldrine, d'endrine et de DDT total variaient entre ces valeurs normatives et un dixième de ces valeurs.

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INTRODUCTION

The organochlorine (OC) contaminant burden of Lake Ontario is the result of municipal and industrial point source discharges; tributary inputs (Frank *et al.*, 1981, 1982; Great Lakes Water Quality Board, 1983a); atmospheric deposition (Strachan and Huneault, 1979; Strachan *et al.*, 1980); the Niagara River (Kuntz and Warry, 1983; Niagara River Toxics Committee 1984); and resuspension of contaminated bottom sediments. A review of organic contaminant loadings with respect to Lake Ontario is given by Strachan and Edwards (1984). Ambient water concentrations of organic contaminants are therefore a function of any or all of these factors and are ameliorated by processes such as sedimentation and burial, or volatilization which either remove or isolate these compounds from the water.

Most of the recent studies of organochlorine contaminants in Lake Ontario have addressed the Niagara River/Lake Ontario pollution problem described by Allan *et al.* (1983) and have focused primarily on the Niagara River plume and the Western Basin of Lake Ontario. Lakewide surveys of organochlorine contaminants in sediments have been conducted by Thomas (1983) and Frank *et al.* (1979), but little has been undertaken with respect to a lakewide assessment for a number of organochlorine compounds in ambient waters of the lake. Only recently has routine monitoring for these contaminants been feasible, as most monitoring techniques could not compensate for the dilution factor of the lake. Consequently, analysis has been limited to compounds present in relatively high concentrations. The development of extraction capability for large volume samples (36 L), coupled with recent advancements in analytical chemistry, has resulted in lower detection limits and a more effective monitoring procedure for organic contaminants.

This study is part of the Great Lakes Surveillance Program of the Water Quality Branch, Ontario Region, Environment Canada. It was designed to identify areas that would warrant more intensive sampling and to locate point sources, as well as to provide a baseline for the evaluation of trends with respect to the selected parameters.

MATERIALS AND METHODS

Whole water samples (36-L) were collected at 14 stations on Lake Ontario from October 3 to 7, 1983. Eleven of the 14 stations (Fig. 1, Table 1) selected were within 10 km of the shore in order to identify near-shore regions that might have elevated levels due to localized input.

Table 1. Station Coordinates

Station No.	Latitude N	Longitude W
1	43°18'52"	79°44'59"
8	43°37'24"	79°27'28"
21	43°18'02"	79°07'06"
24	43°26'29"	79°07'45"
31	43°53'05"	78°27'26"
35	43°21'29"	78°43'53"
40	43°35'19"	78°0C'39"
57	43°16'20"	77°35'32"
71	42°28'32"	76°31'41"
74	43°45'05"	76°31'08"
78	44°05'03"	76°24'37"
86	45°15'13"	79°11'39"
90	44°08'22"	76°49'30"
97	43°57'40"	76°07'26"

Samples were collected from 1 m below the surface by means of a March submersible pump equipped with Teflon-lined braided stainless steel tubing. The sampling apparatus was purged at each station prior to filling the nine 4-L precleaned amber glass solvent bottles which were capped with solvent-rinsed aluminum foil liners. Samples were held at 4°C until extracted, at which time they were brought to room temperature (20°C). An Aqueous Phase Liquid Extractor (APLE) (McCrea and Fischer, 1985) was used to extract the samples. Four litres of dichloromethane (distilled in glass) was used as the extraction solvent. The collected extracts were prepared in accordance with the *Analytical Methods Manual* (Environment Canada, 1979) for the parameters listed in Table 2, with the exception of toxaphene, which was prepared using a modified biota analytical procedure developed by Zenon Environmental Inc., Burlington, Ontario (pers. comm.).

Table 2. Values Reported for Selected Organochlorine Contaminants ($ng \cdot L^{-1}$)

Parameter	Station No.														Range
	1	8	21	24	31	35	40	57	71	74	78	86	90	97	
1,3-DCB	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,4-DCB	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-DCB	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,3,5-TCB	ND	ND	ND	0.079	ND	0.046	ND	ND	ND	ND	ND	ND	ND	ND	ND–0.079
1,2,4-TCB	0.069	0.139	0.163	0.185	0.124	1.360	0.141	0.128	0.117	0.647	0.049	0.022	0.035	0.063	0.022–1.360
1,2,3-TCB	0.084	0.111	0.133	0.140	0.056	0.672	0.024	0.056	0.055	0.065	0.040	0.020	0.048	0.008	0.008–0.672
TeCB2	0.071	0.061	ND	0.024	ND	0.322	0.020	0.009	0.035	0.024	ND	0.009	ND	ND	ND–0.322
1,2,3,4-TeCB	0.037	0.125	0.081	0.082	0.037	0.572	0.086	0.057	0.058	0.091	0.017	0.034	0.014	ND	ND–0.572
PeCB	0.042	0.095	0.097	0.053	0.028	0.220	0.031	0.031	0.031	0.054	0.019	0.037	0.019	0.009	0.009–0.220
HCB	0.068	0.089	0.095	0.043	0.068	0.103	0.036	0.042	0.017	0.033	0.031	0.052	0.034	0.019	0.017–0.103
α-BHC	6.94	8.08	7.78	4.89	8.81	6.89	7.36	4.36	7.97	6.83	4.83	6.53	5.78	6.50	4.36–8.81
Lindane	1.66	1.85	1.18	0.806	1.54	1.47	1.77	0.83	1.05	1.09	1.16	1.60	1.34	0.856	0.806–1.85
Oxychlordane	0.263	0.179	0.213	0.131	0.174	0.156	0.191	0.133	0.160	0.189	0.208	0.191	0.156	0.143	0.131–0.263
Heptachlor epoxide	0.375	0.264	0.362	0.211	0.243	0.167	0.306	0.222	0.299	0.374	0.333	0.236	0.257	0.262	0.167–0.375
α-Chlordane	0.035	0.046	0.022	0.008	0.014	0.014	0.041	0.017	0.008	0.008	0.010	0.020	0.019	0.008	0.008–0.046
γ-Chlordane	0.048	0.062	0.050	0.033	0.048	0.043	0.045	0.028	0.042	0.029	0.026	0.048	0.029	0.037	0.026–0.062
Dieldrin	0.456	0.527	0.453	0.259	0.631	0.352	0.470	0.325	0.442	0.361	0.538	0.510	0.047	0.300	0.259–0.631
Endrin	0.123	0.131	0.083	0.044	0.129	0.051	0.145	0.071	0.089	0.072	0.093	0.093	0.101	0.056	0.044–0.145
Photomirex	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Mirex	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methoxychlor	0.060	0.058	0.052	0.054	0.069	0.086	0.086	ND	ND	0.032	0.052	0.050	0.040	ND	ND–0.086
Total DDT	0.264	0.271	0.107	0.123	0.126	0.108	0.106	0.155	0.069	0.015	0.175	0.231	0.145	0.122	0.069–0.271
Toxaphene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total PCBs	3.100	0.580	0.830	1.140	0.840	1.010	0.430	0.430	0.700	0.320	0.430	0.870	0.720	1.920	0.32–3.1

DCB = Dichlorobenzene.
TCB = Trichlorobenzene.
TeCB = Tetrachlorobenzene.
PeCB = Pentachlorobenzene.
HCB = Hexachlorobenzene.
TeCB2 = 1,3,2,5-TeCB + 1,2,4,5-TeCB
ND = Not detected.

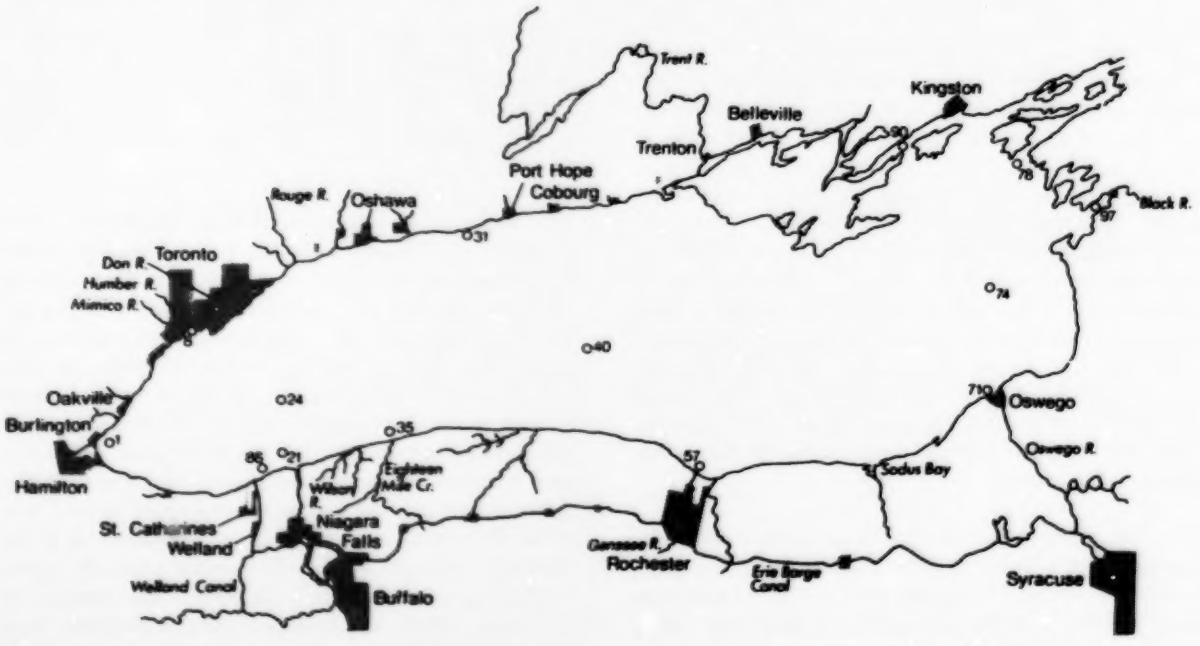

Figure 1. Stations sampled for organochlorine contaminants (depth 1 m).

The operating conditions for the GC/EC analyses were reported as follows:

Column	30 m x 0.25 mm I.D. SE 54
Injector temperature	230°C
Carrier	N_2 at 30 cm/s
Injection mode	Splitless 30 s
Split	30 mL/min
Oven temperature	80° 2-min hold to 160° at 8°/min to 260° at 4°/min, 8-min hold
Detector temperature	350°C
Detector makeup	30 mL/min argon/methane (95/5)

RESULTS AND DISCUSSION

The concentrations and lakewide ranges are listed in Table 2. The corresponding station locations are shown in Figure 1. It should be noted that analyses were done for both parent forms of DDT (o,p'-DDT; p,p'-DDT) as well as the metabolites p,p'-DDE and p,p'-DDD. To provide a better representation of this group, the components were also expressed as total DDT (tDDT). Fifteen of the 23 compounds examined were found to be ubiquitous. Methoxychlor was detected at 11 of the 14 stations surveyed, whereas toxaphene, mirex, photomirex and several of the lower order chlorobenzenes (CB) were not detected at any of the stations (Table 2).

Chlorobenzenes

Analysis of the chlorobenzene groups indicated a widespread distribution with a high degree of intracorrelation (Tables 2 and 3). Station 35, with the exception of 1,3,5-trichlorobenzene (TCB), consistently recorded the highest concentrations for the detected chlorobenzene groups (Figs. 2, 3 and 4). Although these levels may be attributed to inputs from the Niagara River, Eighteen Mile Creek, which is connected to the Erie Barge Canal system and has previously been identified as a source of volatile halocarbons into Lake Ontario (Kaiser *et al.*, 1983), may impact on station 35 contaminant burdens.

The ratio of α-BHC to lindane, the two most predominant OC compounds in Lake Ontario, was used as a tracer to delineate further which of these two sources was influencing the contaminant distribution at station 35. Ratios for the Niagara River, as calculated from concentrations reported in NAQUADAT (Environment Canada, 1984) and by Oliver and Nicol (1984), were 6.7 (n = 145)

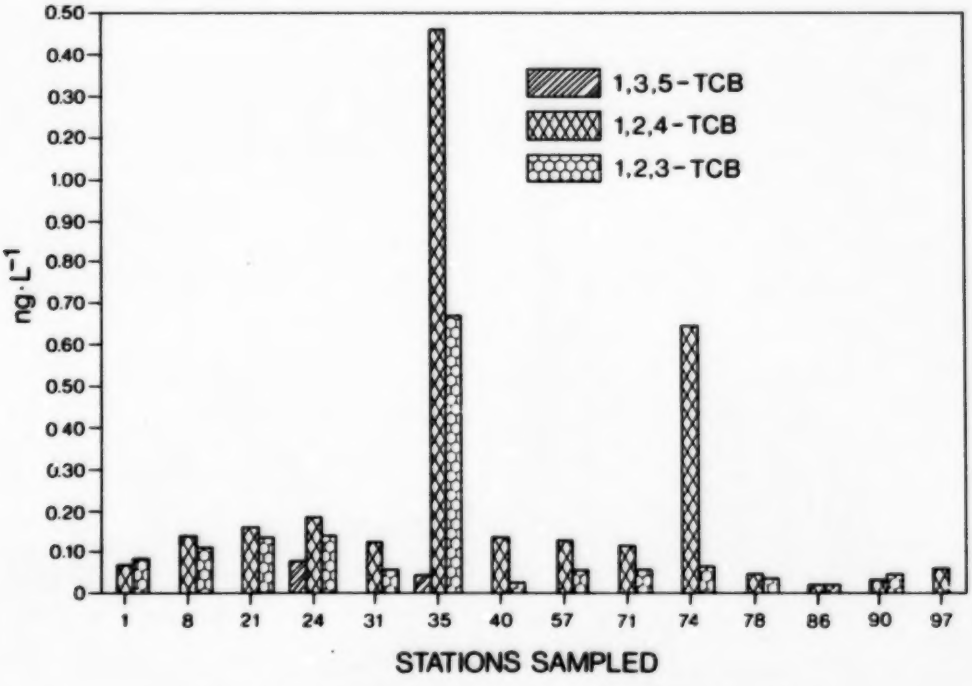

Figure 2. Levels of trichlorobenzenes ($ng \cdot L^{-1}$) at corresponding stations.

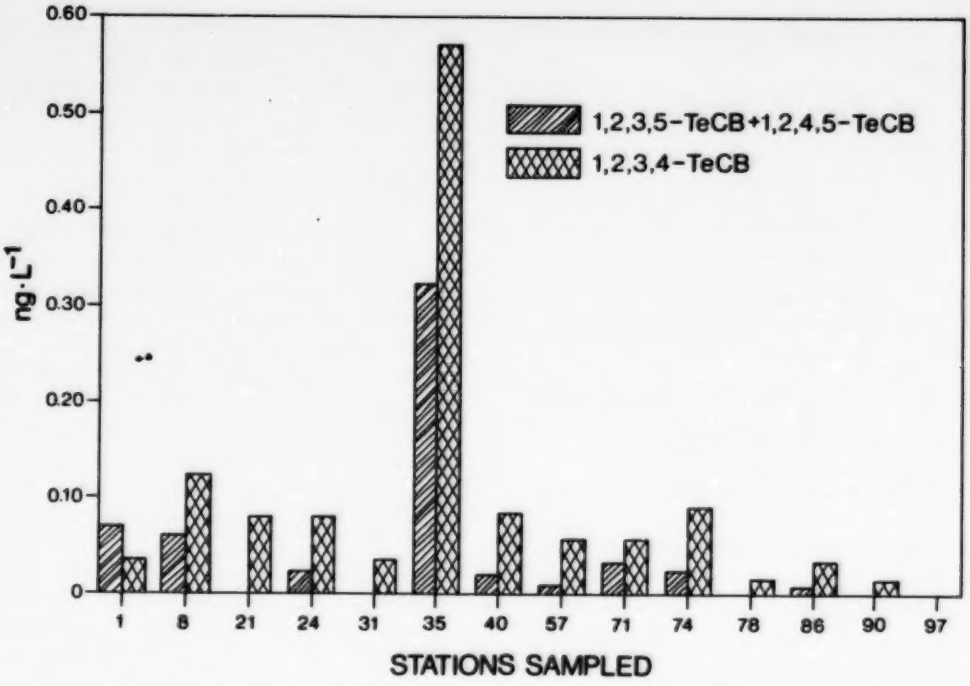

Figure 3. Levels of tetrachlorobenzenes (ng·L^{-1}) at corresponding stations.

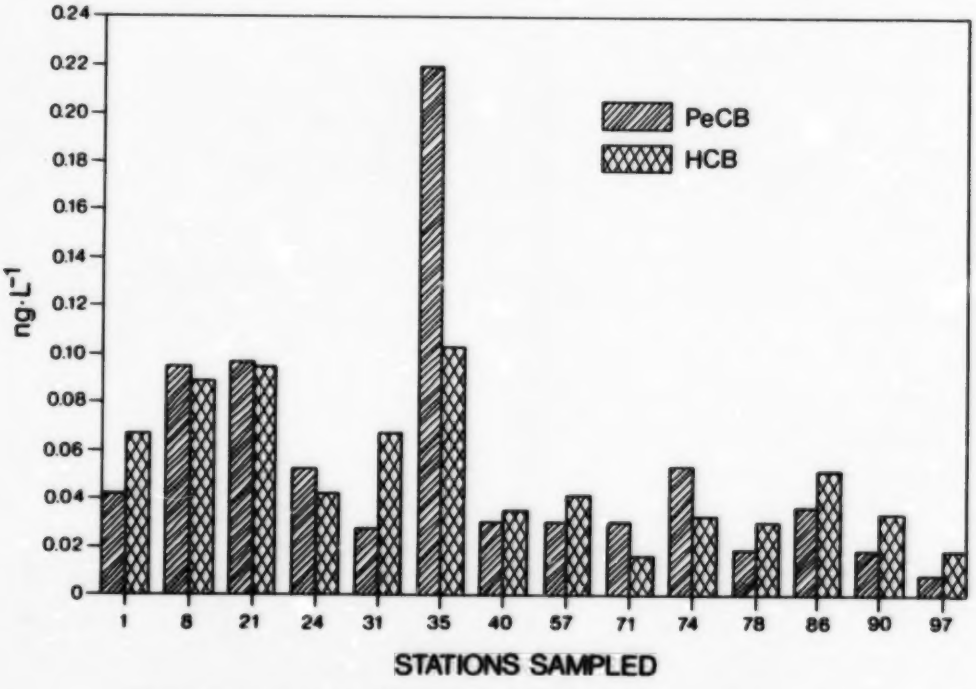

Figure 4. Levels of penta- and hexachlorobenzenes (ng·L^{-1}) at corresponding stations.

Table 3. Correlation Values of Lake Ontario Organochlorine Contaminants (r values > 0.5, p > 0.05)

	1,2,4-TCB	1,2,3-TCB	TeCB2	TeCB	PeCB	HCB	α-BHC	Lindane	Oxychlordane	Heptachlor epoxide	α-Chlordane	γ-Chlordane	Dieldrin	Endrin	Methoxychlor	Total PCBs	tChl	tDDT
1,2,4-TCB	1.00	0.90	0.88	0.93	0.86													
1,2,3-TCB		1.00	0.97	0.98	0.94	0.64												
TeCB2			1.00	0.96	0.90	0.57												
TeCB				1.00	0.94	0.60												
PeCB					1.00	0.78												
HCB						1.00						0.65			0.62		0.57	
α-BHC							1.00	0.57				0.78					0.59	
Lindane								1.00	0.54		0.79	0.71		0.79	0.71		0.83	
Oxychlordane									1.00	0.76				0.54				
Heptachlor epoxide										1.00								
α-Chlordane											1.00	0.67		0.75			0.93	0.61
γ-Chlordane												1.00	0.57				0.90	
Dieldrin													1.00					
Endrin														1.00			0.71	
Methoxychlor															1.00			
Total PCBs																1.00		
tChl																	1.00	0.59
tDDT																		1.00

tChl = α-chlordane + γ-chlordane
tDDT = DDE + DDD + p,p'-DDT
TeCB = 1,2,3,4-TeCB
TeCB2 = 1,2,3,5-TeCB + 1,2,4,5-TeCB

and 7.1 (n = 104), respectively. These values, when compared to a ratio of 4.7 at station 35 (Fig. 5), appear to indicate a limited effect from the Niagara River on station 35 and suggest a more localized source.

A concurrent study by Oliver (1984) on chlorobenzenes in Lake Ontario sampled three stations in common with this study. While levels of tetra- (TeCB), penta- (PeCB), and hexachlorobenzenes (HCB) were similar for the two studies, Oliver reported higher values for 1,2,4-TCB. The lower values for 1,2,4-TCB reported here as well as the non-detection of the di- and other trichlorobenzenes may be attributed, in part, to volatilization losses from the use of a rotary evaporator. Oliver (1984) used a multiple-staged Snyder condenser column followed by a Kuderna-Danish type condenser for the concentration of extracts prior to analysis.

α-BHC and Lindane

As noted, α-BHC and lindane were the two most abundant OC compounds measured, often one to two orders of magnitude greater than the other detected compounds, with the exception of polychlorinated biphenyls (PCBs) (Table 2). Based on correlation analysis of non-transformed data (Table 3), the lakewide distribution of lindane shows significant ($p = >0.05$) similarities to other detected OC pesticides, particularly chlordane (α-chlordane + γ-chlordane) ($r = 0.83$), methoxychlor ($r = 0.71$), and endrin ($r = 0.79$) (Table 3). These similarities may indicate comparable loading patterns and similar resistance to environmental degradation processes. A comparison of lindane with α-BHC was significant, although weaker ($r = 0.57$), as reflected in the variation of the α-BHC to lindane ratio (Fig. 5). This variability may be attributed to the composition of the contributing components, as an α-BHC to lindane ratio of 3:1 was found in precipitation by Strachan and Huneault (1979), whereas the Niagara River was found to have a ratio of 6.7:7.1.

Chlordane

From 1969 to 1972, many of the highly utilized OC pesticides such as DDT, aldrin, dieldrin and endrin were either banned or severely restricted. Chlordane was used as an alternative, although not in the same quantities. Widespread usage of this pesticide throughout the basin has resulted in a ubiquitous distribution for chlordane and its components in the lake. Total chlordane (α-chlordane + γ-chlordane) was found to be highest in the western region

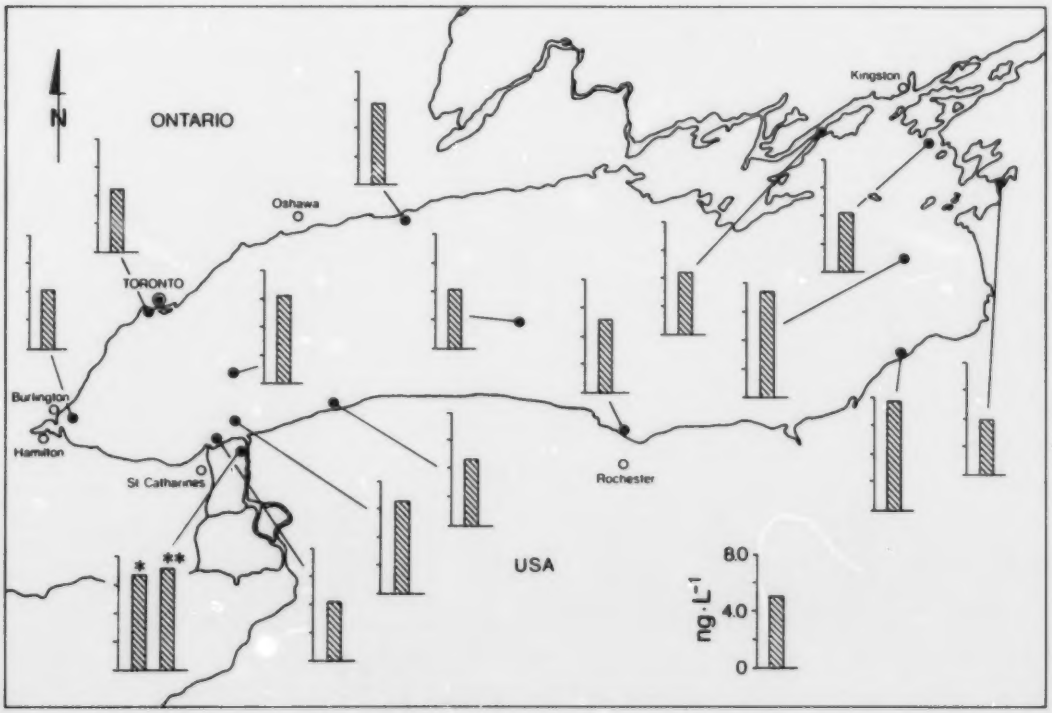

Figure 5. Ratio of α-BHC to lindane (*Environment Canada, 1984; **Oliver and Nicol, 1984).

of Lake Ontario, particularly at station 8 off Toronto (Fig. 6). This is suspected to be the result of both agricultural runoff and urban usage. The contribution by the latter source may exceed that of the former, as suggested by Frank *et al.* (1978), especially since the primary usage of chlordane in agriculture was banned in 1977 (Frank *et al.*, 1982).

Heptachlor epoxide (HE) and oxychlordane are both metabolites of technical chlordane residues. Heptachlor epoxide is derived primarily from the 11% of heptachlor found in technical chlordane, and oxychlordane is a metabolite of α-chlordane and γ-chlordane (National Research Council of Canada, 1974). Although HE could have resulted from heptachlor applications, this is unlikely, as heptachlor usage was limited prior to its restriction in 1969 (Frank *et al.*, 1978). Furthermore, HE is significantly correlated with oxychlordane ($r = 0.76$), which is exclusive to technical chlordane applications.

The relatively high levels recorded for these compounds in water (0.167-0.375 $ng \cdot L^{-1}$ for HE and 0.131-0.263 $ng \cdot L^{-1}$ for oxychlordane), relative to the parent compounds (α-chlordane 0.008-0.046 $ng \cdot L^{-1}$, γ-chlordane 0.026-0.062 $ng \cdot L^{-1}$), may be more a function of solubility than of loading. Chlordane has a reported solubility of 6-9 $ng \cdot L^{-1}$ in distilled water, whereas HE solubility is reported at 350 $ng \cdot L^{-1}$ (National Research Council of Canada, 1974). Oxychlordane, also an epoxide (1,2-dichlorochlordene), is thought to have a comparable solubility. It should be noted that on the basis of chemical structure, these metabolites, although more hydrophilic, may be more toxic (Street and Blau, 1972) than the parent compounds.

Endrin and Dieldrin

Although these pesticides have been restricted since 1969, they are still found throughout the lake (Table 2). Endrin was found to be highest at the mid-lake station (0.145 $ng \cdot L^{-1}$), perhaps due to a lack of suspended sediments to remove the atmospheric contribution from the water column (Strachan and Edwards, 1984). The northwestern region of the lake (stations 1 and 8) (Fig. 1) in the vicinity of the Toronto-Hamilton area also recorded relatively high values for endrin.

Dieldrin levels result primarily from applications of aldrin, which was used in large quantities prior to being banned in 1969 (Frank *et al.*, 1978). Dieldrin was found

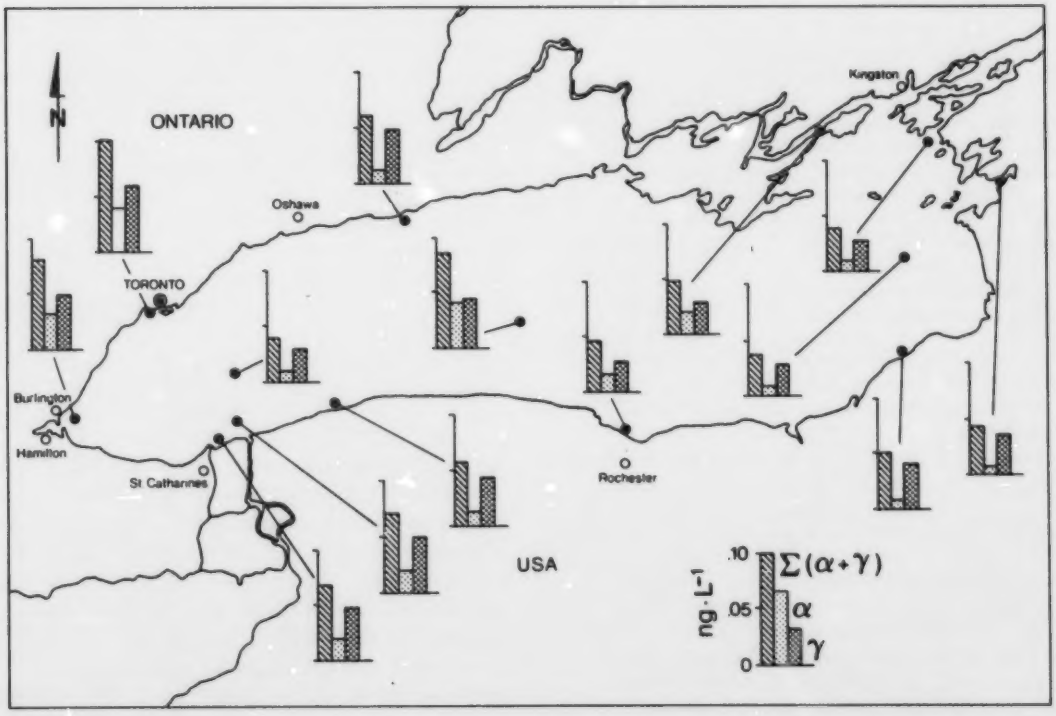

Figure 6. Levels of α-chlordane, γ-chlordane, and Σ-chlordane ($ng \cdot L^{-1}$) at corresponding stations.

to be highest at station 31 in the vicinity of Cobourg, Ontario. These findings are similar to those of Haile *et al.* (1975). Differences in methodology, however, restrict direct comparison of the data. Dieldrin was also found to be higher mid-lake than at some near-shore stations.

tDDT and Methoxychlor

As with other pesticides, tDDT was found throughout the lake, although some components were not detected at every station. The highest values for tDDT were recorded in the western region of Lake Ontario. The parent forms (o,p'-DDT and p,p'-DDT) were detected at 11 of the 14 stations. DDE was found at every station, and p,p'-DDD was detected at 13 of the 14 stations sampled (Table 2). As DDT and DDE have been banned since 1972 in the watersheds of the Great Lakes, the presence of these compounds is thought to be either the result of historical applications or more likely, in the case of the parent compounds, the result of current contributions. Two suspected current non-point sources are atmospheric transport from countries in Central America where usage of DDT products is still permitted or from regional applications of pesticides containing dicofol (Kelthane). Technical dicofol has been found to contain production impurities which include the o,p' and p,p' isomers of DDT, DDE and DDD (U.S. EPA, 1985).

Methoxychlor, the methoxy analogue of DDT which still has limited usage, was detected at all but the three stations located at the southeastern region of the lake (Table 2).

PCBs

The widespread use of PCBs, especially in non-closed systems, coupled with their extreme environmental stability, has resulted in global dispersion of these compounds. Although atmospheric deposition may account for a portion of the loadings, several stations recorded levels that are indicative of localized inputs (Fig. 7). The highest concentration reported (3.1 $ng \cdot L^{-1}$) was at station 1, approximately 3.6 km east of Hamilton Harbour (Fig. 1). This bay has been designated as a Class A site by the Great Lakes Water Quality Board, denoting it as a region of high level pollution, and PCBs are cited as being a major concern (Great Lakes Water Quality Board, 1983b). Exchange of harbour water with the lake through the canal is oscillatory, with a harbour to lake flow of up to 38.4 $m^3 \cdot s^{-1}$ and a net exchange of 7.8 $m^3 \cdot s^{-1}$ (Ontario Ministry of Environment,

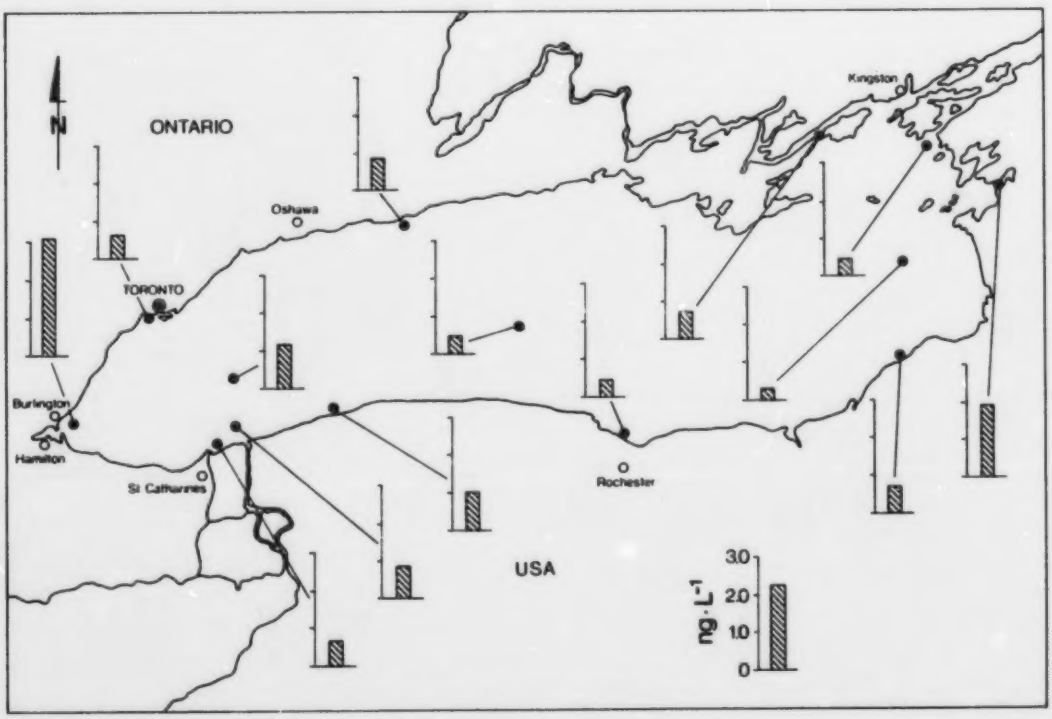

Figure 7. Levels of total PCBs ($ng \cdot L^{-1}$) at corresponding stations.

1985). The resulting input of PCBs to Lake Ontario associated with this exchange is thought to be the major contributor to the levels observed at station 1.

Several other stations were found to have levels greater than 1.0 $ng \cdot L^{-1}$ (Table 2, Fig. 7), in particular station 97 in Black River Bay (1.92 $ng \cdot L^{-1}$), station 24 (1.14 $ng \cdot L^{-1}$) in the Niagara River plume, and station 35 adjacent to Eighteen Mile Creek (Fig. 1). Collin (1980) reported sediment PCB levels of >50 ppb in the Black River. Whether the levels found in the water in this area are due to leaching of in-place contaminants from sediments or to a combination of inputs from other sources has yet to be confirmed.

The Appendix lists the guidelines and criteria established by the International Joint Commission (Great Lakes Water Quality Board) and the United States Environmental Protection Agency (U.S. EPA) for the organochlorine compounds studied. The range of levels detected is also presented. Criteria for compounds such as oxychlordane and heptachlor epoxide have yet to be established. In addition, the potential for synergistic effects that may result from the simultaneous presence of a wide range of compounds is not known.

The range of compounds detected is, in many instances, within one order of magnitude of the above objectives or criteria for ambient water. When the probability of losses in the collection, storage and analytical processes is considered, this apparent margin of safety may be further reduced.

Furthermore, it has been suggested that the U.S. EPA criterion for total PCBs of 14 $ng \cdot L^{-1}$ is possibly one order of magnitude too high, when the potential for bioaccumulation is examined (U.S. EPA 1980). In the event that a criterion of 1.4 $ng \cdot L^{-1}$ be adopted, several regions of the lake would exceed this value.

CONCLUSION

The limited number of samples collected (14) and the absence of replicates to quantify procedural variability limit the ability of this study to assess Lake Ontario with respect to these contaminants. The data do indicate a ubiquitous distribution for many of the compounds and identify some areas such as those regions sampled by stations 1, 8, 21, 24, 35 and 97 that may be receiving localized inputs of contaminants. Routine monitoring for organochlorine contaminants should be incorporated in the existing surveillance program to provide continual evaluation of the water quality of the Great Lakes.

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APPENDIX

WATER QUALITY OBJECTIVES AND CRITERIA

Table A-1. Water Quality Objectives and Criteria

Compound ($ng \cdot L^{-1}$)	GLWQA* objectives	U.S. EPA criteria	Range
Trichlorobenzenes			ND–1.36
Tetrachlorobenzenes			ND–0.572
Pentachlorobenzenes			0.099–0.220
Hexachlorobenzene			0.017–0.103
α-BHC			4.36–8.81
Lindane	10	10†	0.806–1.85
Total chlordane	60	4.3‡	0.034–0.108
Heptachlor/heptachlor epoxide	1.0	1.0†	0.167–0.375 (HE)
Oxychlordane			0.131–0.263
Endrin	2.0	2.3§	0.044–0.145
Dieldrin	1.0	1.9‖	0.259–0.631
tDDT	3.0	1.0¶	0.069–0.271
Methoxychlor	40	30	ND–0.068
Toxaphene	8	13**	ND
Mirex	DL	1.0†	ND
Photomirex			ND
Total PCBs		14††	0.320–3.10

* Great Lakes Water Quality Agreement. 1978. International Joint Commission.
† U.S. EPA. 1976. Quality Criteria for Water (The Red Book). EPA 440/9-76-023.
‡ U.S. EPA. 1980. Ambient water quality criteria for chlordane. EPA 440/5-80-027.
§ U.S. EPA. 1980. Ambient water quality criteria for endrin. EPA 440/5-80-047.
‖ U.S. EPA. 1980. Ambient water quality criteria for aldrin/dieldrin. EPA 440/5-80-019.
¶ U.S. EPA. 1980. Ambient water quality criteria for DDT. EPA 440/5-80-038.
** U.S. EPA. 1980. Ambient water quality criteria for toxaphene. EPA 440/5-80-076.
†† U.S. EPA. 1980. Ambient water quality criteria for polychlorinated biphenyls. EPA 440/5-80-068.
ND = Not detected.
DL = Detection limit.